CHAPTER 15. RADIO FREQUENCY INTERFERENCE MONITORING VANS (RFIM VANS)

1500. INTRODUCTION. The term "RFIM van" is the name historically applied to those motor vehicles used for the location and resolution of spectrum interference problems and attendant engineering measurements. The vehicles have varied from passenger automobiles containing basic RFI equipment, to step-van vehicles, to even large trucks filled with electronic equipment and housing a large power generating system to power it. In this order, the terms "RFIM van" or "van" encompass all those vehicles past, present and future.

a. The RFIM van is an essential tool in the management of the spectrum. Interference resolution is an important part of its function, but it can perform many other vital functions which can be accomplished in no other practical way.

b. There is an increasing need to monitor the spectrum which we use. As more FAA facilities are added, and all around us other users add transmitters and RF emitters so that the already crowded spectrum becomes more crowded, more care must be taken to use wisely the portion of spectrum allotted us. Unless the FMO uses the capabilities of the van to keep abreast of the spectrum environment in the region, it cannot be controlled effectively.

c. While there is a nation-level program to specify a standard van configuration for all regions, currently, the style and configuration of the vans are left to the discretion of the individual regions and FMO's, since it is recognized that geographical and operational considerations vary between regions. The necessity for there being at least one in each region is obvious, and its operation and control shall be the responsibility of the FMO.

1501. CONTROL AND RESPONSIBILITY. The FMO's shall have full responsibility for the operation and care of the RFIM van. As a minimum they shall:

a. Prepare and implement a plan for providing electromagnetic radiation measurement and interference detection and location services to those agency elements having a need.

b. Be thoroughly familiar with the technical equipment in the van and the practical applications of it and possess a good knowledge of any facility equipment under test and measurement.

c. Operate the equipment in the van, record and analyze received data, evaluate results, and prepare necessary documentation and reports.

d. Work closely with AT, FS, and AF to uncover, locate, and eliminate harmful interference.

e. Cooperate with the FCC and other appropriate agencies in resolving harmful interference problems consistent with agency interests.

f. Calibrate critical test equipment at least annually.

1502. RFIM VAN USE. The instrumented van is a potent tool, which can be used for interference location and resolution and the making of many kinds of electromagnetic spectrum measurements. Some of those uses are:

a. Plotting of antenna radiation patterns while the facility operates normally.

b. Interference detection, location and resolution.

c. Spectrum signatures of facilities without disrupting normal operation.

d. Accurate frequency measurements of all facilities without disturbing normal operation.

e. DF capability while the van is in motion.

f. Site electromagnetic surveys and compatibility studies.

g. Coverage and field strength studies.

h. Radiation hazard measurements for nonionized radiation.

1503. INSTRUMENTATION. To assure the capability of accomplishing the items listed in paragraph 1502, the basic van instrumentation, some of which will be provided and some of which will be at the option of the individual regions is as follows:

a. Field strength meters (FSM). While the FAA operates only in certain portions of the spectrum, it is essential that the van have standard field strength measuring equipment, properly calibrated for the spectrum in which FAA operates and contiguous bands. Fortunately, manufacturers have standardized on four ranges. These fit the FAA needs nicely. The first three ranges cover the frequencies used by FAA from LF NDB's through ASR and RCL. The fourth range is needed for ASDE, TML and other new facilities as they are developed. Equipment for at least the first three shall be installed in the van, but so mounted that they can be removed easily for special spectrum projects or temporary use in a FI aircraft when necessary. The four ranges are:

(1) 100 kHz to 30 MHz

(2) 30 MHz to 1000 MHz (1 GHz)

(3) 1 GHz to 10 GHz

(4) 10 GHz and higher

b. An X-Y Plotter (XYP).

c. A spectrum analyzer (SA) covering from Very Low Frequency (VLF) to at least 10 GHz. The analyzer should have X and Y outputs to record received spectra on a standard

X-Y plotter or computer-driven printer or plotter. A higher frequency unit is suggested, considering the ASDE and other upcoming millimeter wave equipment. Like the FSM, the SA also must be calibrated so that it can be used in finite field strength and power density measurements.

d. A Printer to print SA output to hard copy.

e. Appropriate antennas covering at least the same range as the FSM's and SA's. Generally, this will be loops in the L/MF range, frequency adjustable dipoles or biconical antenna for 30-1000 MHz, and horns or helicals for 1+ GHz. Yagis for specific ranges such as LOC are helpful.

f. An antenna rotator mounted on the van to permit rotating the installed antenna from inside the vehicle. A crank-up tower is desirable.

g. An RF signal generator for at least the range up to 1 GHz. This generator is used to generate test frequencies for various van measurements.

h. A frequency counter for at least the range up to 1.5 GHz. While usable for any counting function, it is particularly useful for measuring radar/beacon PRR's fed to it from the FSM. In addition, it permits direct off-the-air measurements of stronger signals.

i. An accurate step attenuator for the range of at least 0-80 dB in 1 dB or 10 dB steps through 10 GHz. Its purpose is twofold:

(1) It can be used for dB step calibration of the XYP and antenna pattern recordings.

(2) It can be used to insert basic attenuation before the FSM to prevent its overload and operation at its greatest sensitivity, inhibiting AGC action, thus permitting linear readouts.

j. Tunable bandpass filters for at least the range 100 MHz-3 GHz. The filters are connected ahead of the FSM or SA to eliminate instrument spurious generation from very strong signals other than the frequency being measured.

k. A high-speed recorder for measuring rapid events, particularly rotating radar antenna patterns. Pen slew speed should not be slower than 5 milliseconds (msec) full scale, in order to follow rotating pattern changes accurately.

l. An oscilloscope for analyzing detected signals from receivers, FSM's or SA's.

m. A cassette tape recorder for recording the sound of received signals. The unit is particularly useful in recording interference signals. If the recorder is dual channel, one channel can be used for interference recording, and the other for voice input by the FMO. This offers the opportunity of putting significant data on the recording without having to write separate notes.

n. A VHF A/G 760 channel transceiver for communicating with ATCT's and FSS's on airports and FI aircraft during interference locating procedures.

o. FM and SSB transceivers, as appropriate, for communicating with SMO personnel, a site under investigation, FI aircraft, and home base via the RCOM.

p. Direct current (dc)-to-117 volts (V) alternating current (ac) inverter for powering low-drain ac powered equipment and charging nicad batteries in equipment in the van. The van auto battery supplies the dc source and is charged or "floated" by the van engine alternator.

q. Gasoline (or diesel) driven generator - 117 V ac of 1.5 to 3.5 kW capacity. This unit is used for supplying ac power to the larger drain units and used when the van is parked with its engine turned off and not charging the van battery.

r. DF system for locating the source of an interfering signal.

s. Ancillary items such as the following are recommended:

(1) Step-recovery diode for extending the frequency meter and generator output to at least 3 GHz for accurate radar and beacon frequency measurements.

(2) Broadband amplifiers for at least 100-1,000 MHz, to permit increased signal level to drive the step recovery diode for microwave measurements above 1 GHz.

(3) Ultrasonic narrow beam detector for locating specific defective insulators or crossarms on power poles which cause arcing and resultant broadband interference.

(4) A Citizens Band (CB) transceiver for receiving road advisories when the van is on long trips. (FMO's are reminded that CB may only be used for receiving information, and not transmitting, unless there is a road emergency involved.)

(5) FM handi-talkie for intercommunicating with the van on interference coordination.

(6) Extra step attenuator for signal mixing.

(7) Altimeter and compass for altitude and azimuth determination with respect to the measured site.

(8) A radar beacon transponder mounted in the van, used only to work with AT and FS to positively locate the van on a radar scope when working on radar measurements or interference problems.

(9) Global Positioning System (GPS) receiver.

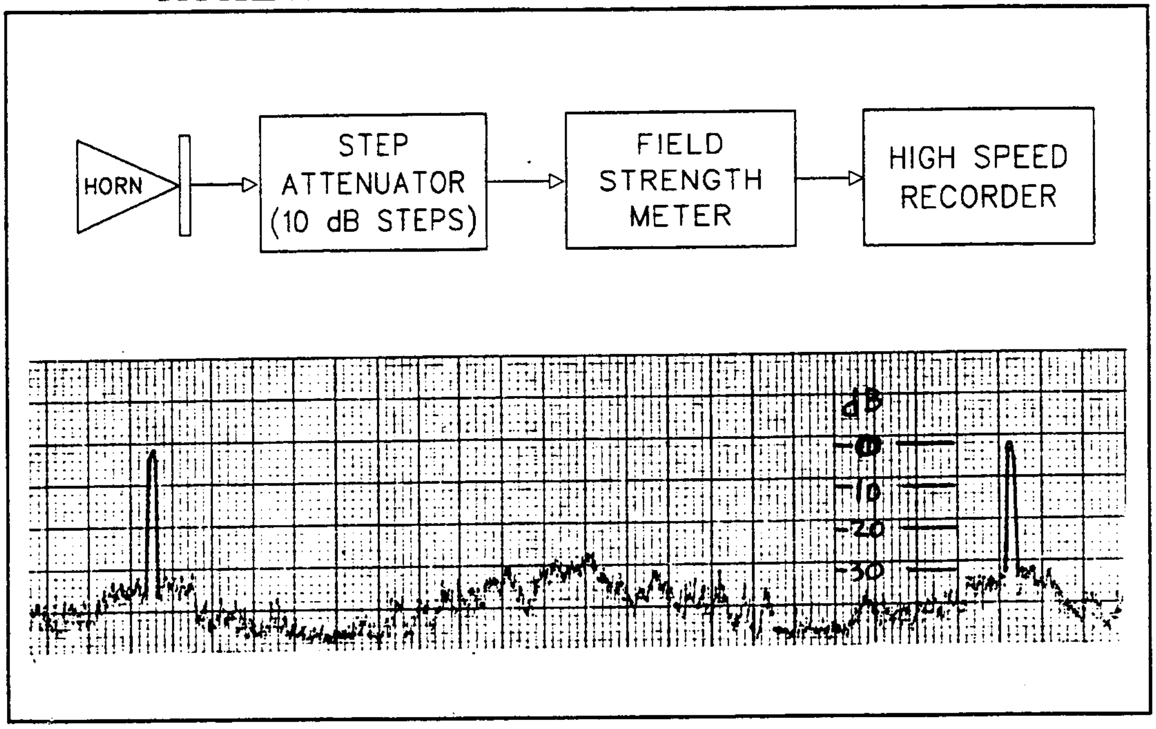
(10) Cellular telephone.

1504. VAN SYSTEM OPERATION. Operating the various systems in the van requires knowledge, training, and skill. While there are several independent systems, they all merge into one total monitoring and measuring system. Yet each component has unique value and associated caveats. The FMO must remember that measurements and follow-on documentation can have widespread affect on the various agency and regional programs and can ultimately affect the safety of flight. The FMO's work may have to be presented in court. Thus, all measurements and documentation resulting must be handled within the highest professional standards. The following paragraphs will deal with instruction and examples of each system operation.

1505. RADAR AND ATCRBS ANTENNA PATTERN RECORDING. Radar antenna pattern recording is a valuable product of van operation. It permits actual radiation pattern recording from any point in space the measuring equipment can be located. It can be accomplished without the radar having to shut down or make any changes in its normal operation, unless the measurements are made to permit various patterns to be measured as the antenna or transmitter functions or hardware are changed. Done correctly, the measurement permits the FMO to determine whether the radar and beacon radiated patterns are normal as well as the directional and nondirectional pattern ratios of SLS operation. If properly skilled, the FMO can make this determination on the spot, within the time it takes to record one revolution of the radar antenna, usually between 5 and 15 seconds. The results then can be radioed to the site, to the SMO, or whomever desires the information, so that go/no-go decisions can be made immediately. An SA with coupled printer or a computer controlled spectrum analyzer (CCSA) with coupled printer provides superior results. But until all vans have such equipment, the FSM/XYP is the best alternative procedure.

a. Primary radar antenna pattern plotting with FSM/XYP is basic and requires only these devices: a receiver (including an SA), a high-speed recorder, a calibrated step attenuator and a suitable calibrated antenna with a stable mount. **NOTE**: The procedure below is specifically for an FSM as the receiver, but use of an SA will be similar except for some steps. Many SA's can be manually tuned which simulates manual tuning of an FSM. See figure 15-1.

FIGURE 15-1. RECORDING SETUP AND SAMPLE TAPE



(1) Set the step attenuator to its highest attenuation (80 to 100 dB) to prevent damage to the FSM from high level signals.

(2) Connect the appropriate horn antenna to the input of the attenuator, with the output of the attenuator connected directly to the input of the FSM.

(3) Set the FSM or SA internal attenuators to zero, to prevent AGC action from giving nonlinear readouts.

(4) Set the antenna for proper polarization. If in doubt, try both horizontal and vertical polarization of the horn and use the one giving highest signal level. Usually, there is about 15 dB difference between correct and reverse polarization indications. Adjust the azimuth to approximately the radar direction.

(5) Tune in the radar on the FSM. This probably will require carefully reducing the step attenuator in 10 dB steps while tuning the radar frequency. Adjust for on-scale meter and recorder or SA readings by noting the peak pass recorded on the recorder. The direct peak function of the FSM can be used for this careful tuning process IF THE RECORDER IS TURNED OFF. An SA can be used in its peak hold mode.

(6) Set the FSM bandwidth to 1 MHz or nearest value.

(7) Carefully rotate the antenna in azimuth for maximum signal to the FSM. This will take a little time since the signal will be varying widely in intensity as the radar rotates. Increase the step attenuation if it becomes necessary to keep an on-scale reading.

(8) Set FSM function to quasi-peak, slide-back peak, or whatever will give a time constant of about 10 msec without "dump." NOTE: In direct peak function, the EATON NM-65T FSM will inject a reverse voltage at the end of the store time to restore the meter to a low value quickly, readying it for the next peak pass. The high speed recorder will slam against its lower reference level and could be damaged due to the large reverse voltage applied. The FSM meter, with its slow ballistics due to damping, will not be slammed.

(9) Connect the high-speed recorder to the Y or signal output of the FSM. NOTE: If the recorder has been carefully calibrated before, only a quick check of levels would be required. If not, calibration must be done at this time before any of the instrumentation controls are touched. Calibration of the high-speed recorder is discussed in paragraph 1506.

(10) Adjust the attenuator so that a near maximum scale reading is received when the radar is "searchlighting" the van, the maximum signal to be received.

(11) Record at least one full pass of radar illumination, with two or three consecutive being preferable to average out any quirks in propagation, such as aircraft fly-through, a passing vehicle's ignition noise recorded, etc.

(12) Analyze the recording briefly and advise anyone waiting for the information by radio. Retain the recording for followup detailed analysis and documentation.

b. Primary radar antenna pattern recording with a CCSA coupled with a printer will provide superior results. The basic setup is similar to FSM/XYP, except those components are replaced with a CCSA and associated printer. Many of the 12 items in paragraph 1505a are applicable, particularly those regarding preventing overload and nonlinear readout.

(1) The advantage is that the CCSA does its own internal calibration and prints it and the grid scale values on the printer recording.

(2) Expanded prints of the radar beam can easily be obtained by merely programming the CCSA before a recorded/stored pass.

(3) Examples of CCSA printouts (reduced from normal 8½" x 11") are shown in figure 15-2.

FIGURE 15-2. EXAMPLES OF ANTENNA PATTERNS ON CCSA PRINTOUTS

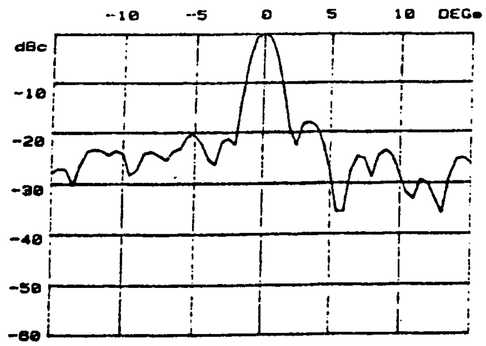
hp

10 dB/

POS PK

ATTEN 10 dB

ANTENNA PATTERN MEASUREMENT



3 dB BEAMWIDTH = 2.5 DEGs
6 dB BEAMWIDTH = 3.5 DEGs
BEAM AMPLITUDE =-22.0 dBm
RPM = 12.7

CENTER 2.844 220 000 GHz SPAN 0 Hz
RES BW 1 MHz VBW 3 MHz SWP 6.95 sec

QMV ARSR FROM HALF MOON BAY 5/29/85 SLS ON MS #1

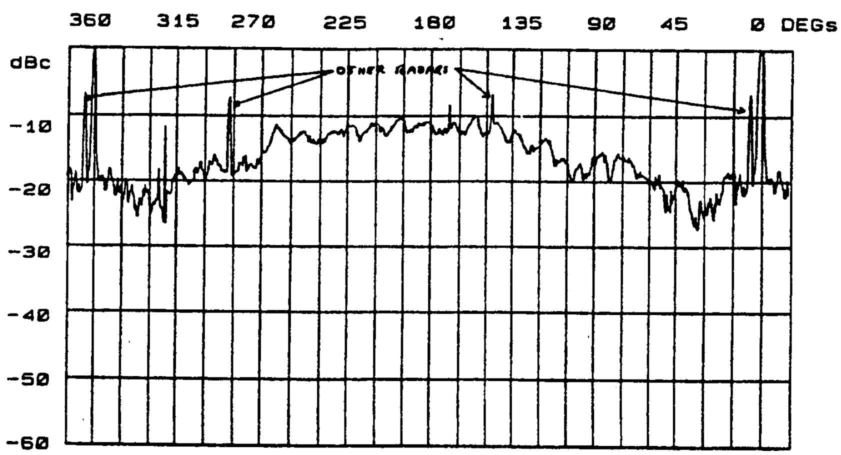
hp

10 dB/

POS PK

ATTEN 0 dB

ANTENNA PATTERN MEASUREMENT



3 dB BEAMWIDTH = 2.5 DEGs
6 dB BEAMWIDTH = 3.5 DEGs
BEAM AMPLITUDE =-43.9 dBm
RPM = 5.0

CENTER 1.030 000 000 GHz SPAN 0 Hz
RES BW 1 MHz VBW 3 MHz SWP 16.1 sec

c. Beacon antenna recordings are done the same way, except for two conditions.

(1) The FSM or CCSA bandwidth cannot be less than 1 MHz to prevent the possibility of signal processing error due to the difference of pulses transmitted by the directional and omnidirectional antennas.

(2) Two plots must be made, one immediately after the other, with the SLS omni on, then off. This allows the FMO to assure that there is no "punch through" of the directional signal on the normal SLS radiated pattern.

d. Pattern recording considerations. The previous list in paragraph 1505a of "how to" gives instruction on the actual recording process. However, every bit as important are the special considerations that must be evaluated for each measurement.

(1) Knowing the monitoring site location with respect to the radar being measured is very important. Using maps for azimuth and distance and the on board altimeter, a close estimate of location can be obtained. If the van has a beacon transponder and previous arrangements have been made with AT, a reading of the transponder's distance and azimuth from the associated radar coupled with the on board altimeter, can give an exact location of the van. Use of a GPS receiver is recommended.

(2) From the location determination, the vertical angle between the monitoring site and the radar antenna site can be calculated. This is a critically important determination. If the site is at 0° vertical angle or lower to the calculated vertical angle of the radiated beam, the recording and resultant plot should be considered as reference only. It is useful for checking radiating patterns at later dates, but should not be submitted as the actual pattern. This is because the beam "nose" will be above the recording site, and thus all references to signal levels which are used to plot the ultimate pattern will not have the correct "nose" reference and be faulty. Below 0°, the antenna pattern cuts off rapidly, while above 0° it falls off slowly so that only very little error ensues, even for a few degrees. A site vertical angle of a degree or so above the beam line is best.

(3) An elevated monitoring position is essential. However, in mountainous terrain, reflections can lead to false levels at some azimuths with respect to the radar. When in mountains, make a second recording a few feet or a few hundred feet away, to assure the first site was a valid nonreflective site and vice versa. A quick comparison of the two recordings can determine any appreciable differences.

(4) When a good monitoring site is not available, the alternatives must be considered. Sometimes the top of a building can provide a suitable site, if the measurement is made from the roof edge nearest the radar to reduce or eliminate reflections. If the radar antenna is not mounted too high, a "cherry picker" can be used to get to the proper height. In this case, however, it must be assured that the FSM is properly shielded to provide a sufficient dynamic range of recording. This can be checked by placing a metallic cover cap or shorted coaxial connector over the antenna input terminal. Whatever signal level is recorded should be due to leakage. If that peak level with the cap over the input terminal is 40 dB or more below the level indicated with the horn antenna connected normally, the recording can be considered accurate, at least down to that level.

(a) If none of these alternatives are possible, then the situation of a "reference only" recording must be considered.

(b) Helicopters and aircraft have been tried, but have not given good results due to the instability of the measurement platform for the period of antenna revolution.

1506. HIGH-SPEED RECORDER CALIBRATION AND OPERATION. The following are the general recommended procedures:

a. Calibration. Setting the zero and span controls is necessary to establish levels that can be relied upon from measurement to measurement. A calibration can be accomplished right on the tape itself. This is done by using the incoming signal which is recorded as the source for calibration of this recording only. After normal pattern recording, slow the tape speed to the slowest practical. While the tape is recording, insert successive 10 dB steps of attenuation between each illumination so that each pass represents 10 dB less level. Adjust the span control so that the 10 dB marks coincide with the tape horizontal lines.

b. Operation. Depending on the speed of antenna rotation, the tape pull rate should be 25 or 50 mm/sec. This allows a good resolution of higher speed ASR plots, while still not making the ARSR plots too long physically. If the recorder has easily changed speed ratios, it is most beneficial to be able to reduce the rate to 5 mm/sec or so when calibrating or tuning the system. This allows accuracy in reading the peak recorded, yet does not waste yards of tape for those functions. If speed change is not easily done, the recorder can be turned off between radar passes for calibrating, to save recording tape.

c. Documentation. While the FMO now has a completed tape, it is of little value to anyone until it is incorporated into a technical report of the operation. Reproduce the tape as recorded, but include calibration marks so that anyone can read it. In addition, affix an identification label which includes date, time, location, source (FMO) and any other pertinent data. The calibration should be shown directly on the tape, with the "nose" of the pass indicating 0 dB and other declining dB levels as minus, e.g., -10 dB, -20 dB.

1507. SPECTRUM ANALYSIS. Analysis of any segment of the spectrum is valuable for planning and problem solving and can be done in three ways. One uses a spectrum analyzer with photographs taken of the scope presentation. The second uses an FSM and XYP. The third uses the CCSA system to do it all.

a. Spectrum analyzer photographing of a rotating radar is relatively easy to obtain, but generally does not yield as high a resolution as an XYP or CCSA.

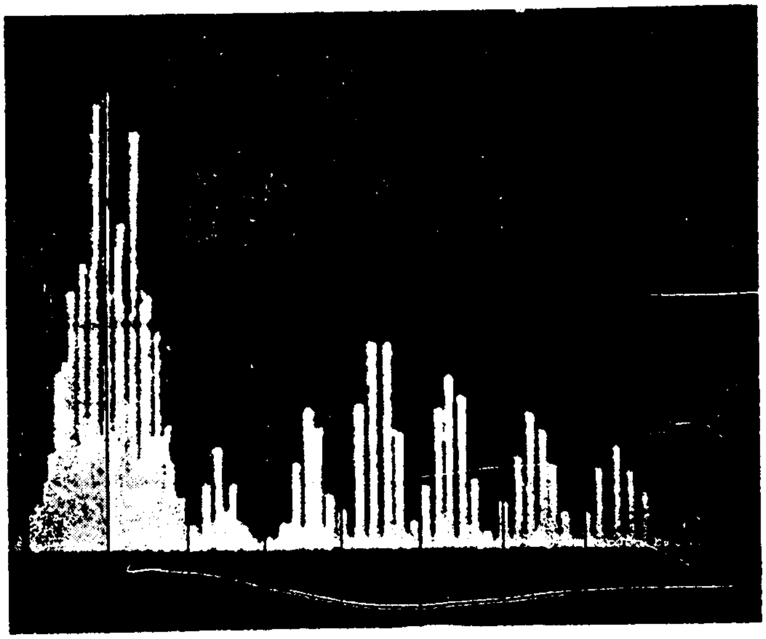
(1) If the antenna is stationary, plotting is easy. Merely scan the portion of the spectrum desired. Then use a scope camera and take a picture of the spectrum appearing on the screen, but allow aperture opening long enough to obtain a full scope sweep.

(2) If the antenna is rotating, it will be necessary either to:

(a) Allow several passes to accumulate on the screen in the storage mode before taking the scope picture.

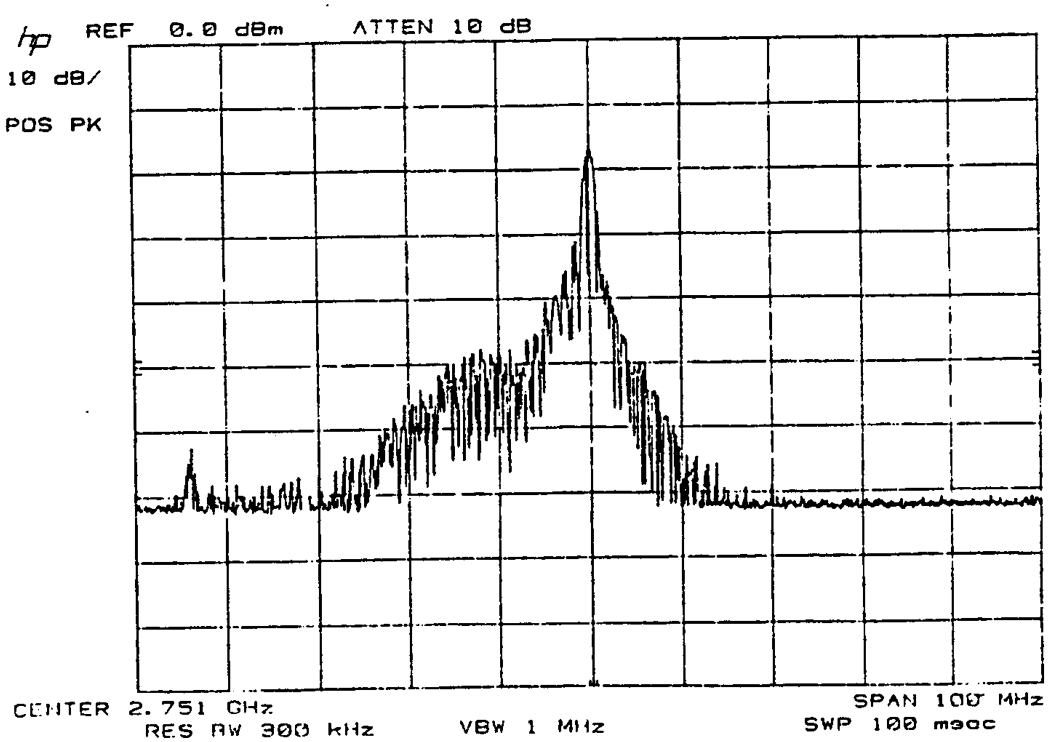
(b) Open the camera shutter while it is on the scope and allow several passes (6 to 10 is recommended) to allow the camera to act as the storage medium. An example of a spectrum picture from a spectrum analyzer is shown in figure 15-3.

FIGURE-15-3. PHOTO OF SPECTRUM FROM A SPECTRUM ANALYZER



b. The advantage of using a CCSA is readily seen in the reduced size spectrum plot shown in figure 15-4. Here, the amplitude (Y), frequency range (X), bandwidth, storage time, and all essential parameters are fed into the computer. Upon command, it simply stores, then prints or plots.

FIGURE 15-4. CCSA-PRODUCED RADAR SPECTRUM PLOT



c. XYP recordings are much more complicated to do, but excellent resolution is the reward, particularly if a CCSA system is not available. However, the process of setup is complex and requires some explanation.

(1) The XYP essentially takes an X axis variable voltage to provide the frequency base of an X-Y plot. As the FSM is tuned from a reference frequency to a higher frequency, the X output voltage increases in a linear manner with respect to frequency. Once the frequency range to be scanned is established, the FMO must then set up the plotter so that its baseline represents a calibrated frequency line.

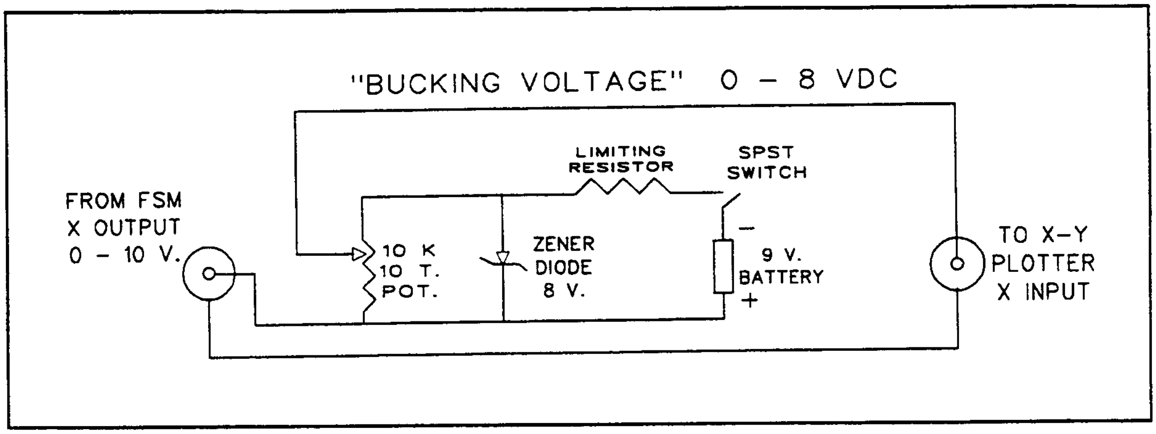
(2) Most FSM's have variable output X voltage directly proportional to frequency. That is, on a 1 to 10 GHz frequency range, the FSM linearly provides 1 to 10 V dc for the XYP X axis. The problem is that the XYP normally has only a 0 to 1 V recording range and a dc "bucking voltage" capability is required to permit zeroing the left edge of the plot when the FSM X output voltage is greater than 1 V.

(a) Assume an ASR spectrum is to be plotted and it is desired to plot from 2650 to 2950 MHz. That means that when the FSM tunes from 2650 to 2950 MHz to cover the whole page, the X voltage supplied the XYP will be 2.65 to 2.95 V dc, respectively. But since the XYP is designed to only handle 0 - 1 V dc and it can only "buck" 1 V dc, the recording would be impossible. The recorder would be hard against the right margin trying to reach a nonexistent 2+ V position.

(b) The solution is to provide an in-line variable "bucking" voltage. This can be accomplished by placing a 10/1 voltage divider across the X output of the FSM. But this is not the best way to go. Some XYP's draw significant current through their X inputs, since it is only a variable voltage divider in the first place. Any additional voltage divider then would be very nonlinear.

(c) A better solution is to build a stable and variable "bucking" voltage source to be placed in line with the X output of the FSM. The basic dc source can either be an ac driven transformer low ripple dc supply, or a simple battery with a zener diode. With the battery, of course, provision must be made for shutting off the battery when not in use. A schematic diagram of a suitable "bucking" device is shown in figure 15-5.

FIGURE 15-5. A DC BUCKING VOLTAGE SYSTEM FOR X-Y PLOTTERS



d. Baseline calibration of an X-Y plot is a process that takes some time, but takes less as the FMO becomes familiar with it.

(1) Connect the "bucking" voltage in reverse series.

(2) Turn on the FSM and tune to the LOWEST frequency to be scanned.

(3) Connect the X and Y outputs of the FSM to the XYP.

(4) Turn on the XYP with the pen lifted. Unless by chance the "bucking" voltage and FSM X output voltage are nearly identical, the pen will go hard left or right. Immediately adjust the bucking voltage control to bring the pen on scale.

(5) Use the XYP zero control as a vernier to put the pen on the zero left hand mark of the paper being recorded upon.

(6) Tune the FSM to the HIGHEST frequency to be plotted.

(7) Now adjust the XYP span control so that the pen is on the right hand mark of the paper to be recorded upon.

(8) Tune the FSM to the LOWEST frequency to be recorded again and note the position of the pen. Most likely, it no longer will be on the zero mark previously set. This is because there is some interdependence between the two controls.

(9) Tuning the FSM between the two limits of frequency to be recorded, carefully "jockey" the zero and span controls until the pen exactly coincides with the frequency span of the FSM between minimum and maximum frequencies to be recorded.

(10) To improve the frequency accuracy of the base line of the plot, it is wise to inject a small signal from the signal generator into the FSM to positively locate an accurate frequency mark on the plot. For instance, if 2700-2900 MHz were being recorded, it would be wise to inject alternately 2700 MHz then 2900 MHz with the "jockeying" so that the two ends are accurately marked. With the linearity of the X output, the frequency marks from the grid paper on the plotter can be assumed to be reasonably accurate.

e. Y axis setup.

(1) Set the FSM function to "Log."

(2) With the FSM tuned off frequency or the input temporarily disconnected so that the pen will drop down to its lowest voltage level to be recorded, adjust the Y axis zero control so that the pen is a quarter of an inch or so above the bottom line on the grid paper.

(3) With the pen still up, carefully tune the FSM to the center of the radar frequency.

(4) Adjust the XYP Y output control so the peak of the pen sweep on illumination by the radar goes up to 75 or 80 percent of full scale.

(5) Set the IF bandwidth to 0.5 or 1.0 MHz.

(6) Tune the FSM to the lowest frequency to be recorded (all the way to the left of the paper grid) and recheck the X axis zero level to assure no drift has occurred while setting up. Readjust zero and span if necessary.

f. Plotting can now start.

(1) Tune the FSM to the start frequency and lower the pen to the paper. Allow sufficient time for at least one radar beam pass.

(2) Carefully move the tuning a very small increment and wait for another pass. It is important not to move the tuning while the beam is illuminating the van. Time the moves so that they are made near the back lobe pass. It is essential that once a plot has begun, tuning be continued in the same direction. There are both electrical and mechanical backlash, however small.

(3) Continue advancing the frequency in very small increments until a definite pass is indicated. Then move in increments small enough to give the resolution desired. When tuning is nearing the peak, reduce the advances to very small amounts, about the width of a pen stroke, to assure a very high resolution plot.

(4) Continue to the end of the plot space. Lift the pen.

(5) When the plot is completed, tune the FSM back past the peak. Then carefully approaching from the same increasing direction, precisely tune in the peak again. LEAVING ALL OTHER CONTROLS UNTOUCHED, use only the X zero control to move the pen to almost the left edge of the paper grid.

(6) Drop the pen onto the paper for just one pass, then lift it quickly again.

(7) With the X zero control, move the pen just slightly to the right.

(8) Using only the in-line attenuator, add 10 dB attenuation.

(9) Lower the pen and record one pass. Lift pen. Repeat these sequences until the attenuated peak pass signal is at a very low level, but not lower than -70 dB or so. It will be less if the plot is started well into the emitted spectrum. The plot is now completed.

g. Documentation. As with the antenna plots described before, the completed spectrum plot needs to be properly labeled and identified. Frequency marks should be placed at the bottom of the plot, at appropriate locations. Using the amplitude calibration marks, horizontal lines should be drawn to indicate levels. A sample plot is shown in figure 15-6.

h. Discussion. Figure 15-6 provides a highly defined emitted spectrum plot, accurately keyed to a frequency base. In essence, the FSM has acted as a very slow-moving focal plane shutter camera, imprinting a "slice" view sequentially on the paper. The reason for the on-plot signal source calibration is twofold:

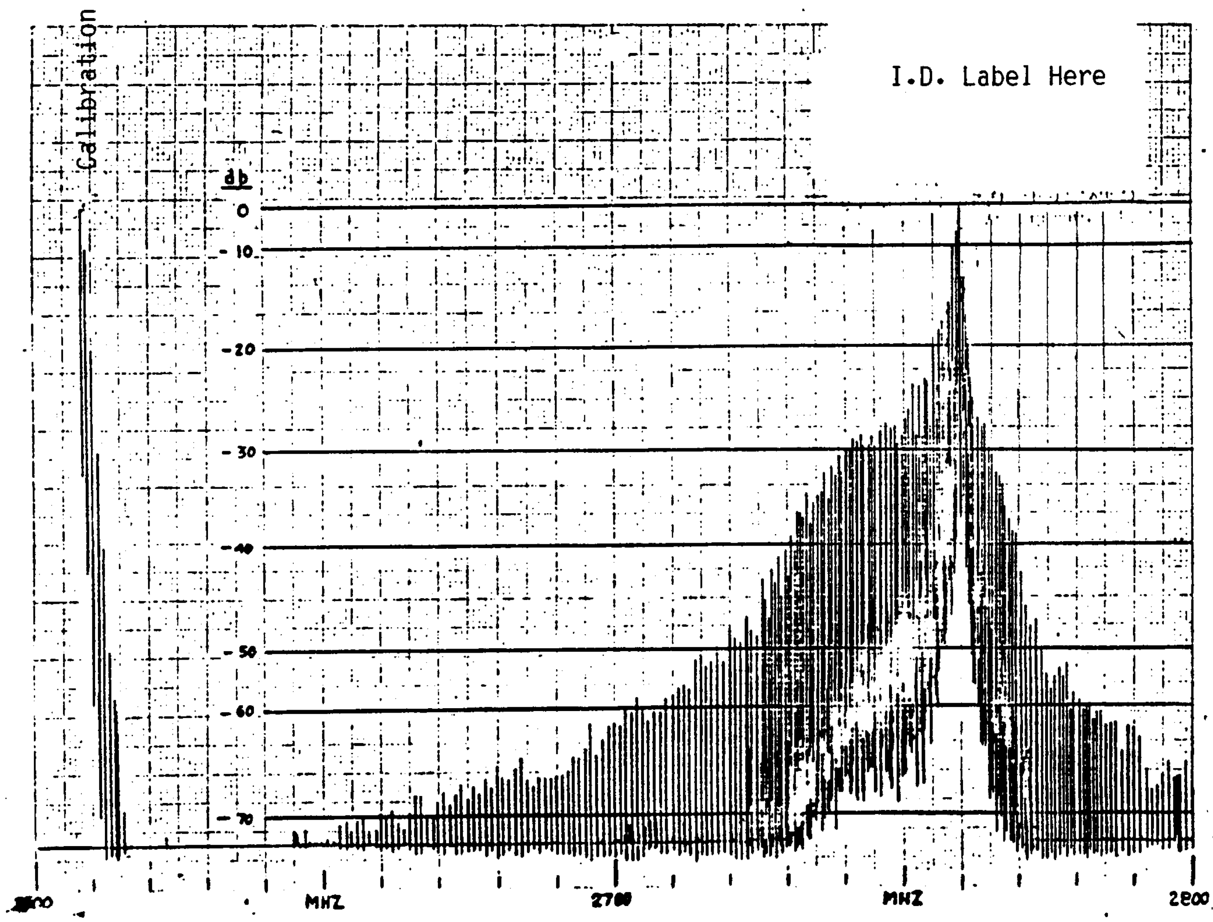
(1) It verifies the accuracy of the spectrum plot at time of review.

(2) It integrates all the limiting factors (any lost signal due to reduced bandwidth, ballistic drag of the plotter pen drive system, etc.) so that the spectrum overall accuracy is assured.

(3) If only 50-60 dB dynamic range is required, the 10 dB steps will be quite linear. But if a larger dynamic range is desired, it will be necessary to compress the upper 10 dB, in order to accommodate the wide dynamic range. This is because most FSM's have only a 60 dB dynamic meter range. There might be small nonlinearities noted between 10 dB levels. A check on any steady signal, using a similar on plot calibration verified by comparison with the FSM panel meter, may show that the in-line attenuator may not be perfectly linear, but should be $< \pm 2$ dB.

i. If the signal being plotted has a stable level such as a radar "searchlighting" the van, or a VOR or TACAN, the same procedure would be used, except the tuning could be done slowly but continuously, completing the plot in a minute or so. If the FSM has automatic frequency scan, that could be used, so long as the scan rate is slow enough to allow the damped pen to respond accurately to variations as it is moved across the page.

FIGURE 15-6. SAMPLE SPECTRUM PLOT OF A ROTATING RADAR



1508. FREQUENCY MEASUREMENTS. Frequencies usually are measured in one of two basic ways. The first is by direct means, the second by indirect means using a transfer standard. Both are easily accomplished in the van.

a. Direct measurement is done simply by using a frequency counter or frequency meter. The incoming signal is fed to the counter and read directly.

b. Indirect measurement uses a signal generator or other frequency meter and a receiver or SA. The desired signal is tuned in on the receiver or SA. An accurate calibrated signal source is also fed into the same receiver or SA through a variable attenuator, so that an appropriate ratio between the signal and the generator can be set. By vernier adjustment, the generator is adjusted to exactly the center of the spectrum distribution peak. In cases of a very strong signal to be measured, the signal is centered in the pass band of the receiver or SA scope. The signal is temporarily removed and the generator is fed to the receiver directly. The generator is then centered on the receiver or SA scope and the frequency read from the generator or from another accurately calibrated source measuring the generator. Most CCSA's have frequency measuring functions built in, either a marker with frequency is shown or the center frequency on the screen is measured and printed out in the spectrum plot.

c. Extended indirect measurement is usually used only for frequencies above 1 GHz, unless a very accurate signal generator is available for the microwave range. Most combination signal generators and frequency meters cover from lower frequencies up to about 1 GHz. To measure frequencies accurately above 1 GHz, the lower frequency generator is used, driving a step-recovery diode. This set up permits abundant harmonic output of the driving generator frequency and carries its level of accuracy. However, a step-recovery diode needs in excess of 1 V of RF to push it into harmonic generation. Using whatever generator is available in the van, add a small microwave amplifier, which in turn drives the diode with 1+ V, which will produce harmonics up to the 10th.

d. For instance, an accurate measurement of 2755 MHz can be done using the transfer standard method by generating a 275.5 MHz signal, with the output signal at 2755 MHz at the 10th harmonic. Other harmonics are generated as well, so care must be taken to ensure the right harmonic is being used. Accuracy of the 2755 MHz signal will be equal to the generator; e.g., if the generator is accurate to .00001 percent, the 10th harmonic will also be accurate to .00001 percent.

e. Accuracy resolution must be considered. Even though a meter or counter might have a 9 or 10 digit readout, the manufacturer's accuracy specification must be adhered to. A measurement of 10^{-8} resolution is meaningless if the instrument is only accurate to 10^{-6}. For example, an indicated measurement of 110.05061 MHz on an instrument of only 10^{-6} accuracy should be rounded off to 110.051 MHz to be commensurate with the instrument's limit of accuracy.

1509. OFF-THE-AIR PRR MEASUREMENT. PRR's can be measured off-the-air in several ways.

a. Direct pulse rate measurement instruments provide reasonably accurate PRR measurements by sampling a radiated spectrum, removing the pulse elements, and automatically predicting the total rate per second. Sampling rates can be as short as 50 µsecs. These instruments are very expensive.

b. Detected pulse rate measurement is commonly used. The process consists of taking detected video from the output of an FSM or SA and feeding it directly to a frequency counter. Most simple counters are designed for CW signals and may not respond well to a pulse signal. One way to solve this is to take the detected video and feed it first into a resistor/capacitor (RC) time delay circuit which will somewhat approximate a sine wave, then to the counter so it will read accurately.

(1) A Time Constant (TC) circuit, formed by a 10K ohm resistor and a 0.25 microfarad (µfd) capacitor will frequently be sufficient without reducing the signal too much. The FMO should experiment with a steady state pulse signal, while watching it on a scope, varying the TC to produce a reasonable replica of half a sine wave. Signal shaping which will give stable PRR readout is the goal.

(2) A varying pulse signal, such as from a rotating radar, requires that the gate time of the counter be varied so that it does not include the actual searchlighting of the van. This large change in signal level can upset the gate counting cycle and give an unrepeatable PRR.

c. Oscilloscope PRR measurements are also very useful for widely varying amplitudes of signal.

(1) In one use, the video output of the FSM or receiver is fed to a calibrated scope. The sweep is set to trigger on the leading edge of a pulse. By adjusting the trigger level, a quite stable pulse presentation can be presented on the scope. The pulse period can be determined from the scope graticule and its calibration. The PRR is simply the reciprocal of the period. The accuracy is limited by how accurately the pulse period can be read. For example, a period of 2700 µsec measured would translate into 1 ¸ (2700 X 10^{-6}) = 1 ¸ .0027 = 370.3, or approximately 370 pps.

(2) In another use, the video output of the FSM or SA is fed to channel 1 vertical input of a two-channel scope. Using a function generator set for triangular wave output, connect it to channel 2 vertical input of the scope and a frequency counter. Set the trigger to channel 1. Refer to figure 15-7 for a typical setup. Either use the scope add function or position each of the channel presentations so that the detected pulse rides the peak level of the triangular wave. Adjust the triangular wave frequency until two consecutive peaks exactly match two consecutive pulses . Read the PRR from the frequency counter. Figure 15-8 shows correct and incorrect presentations for accurate measurement conditions.

FIGURE 15-7. BLOCK DIAGRAM OF ONE METHOD OF MEASURING PRR

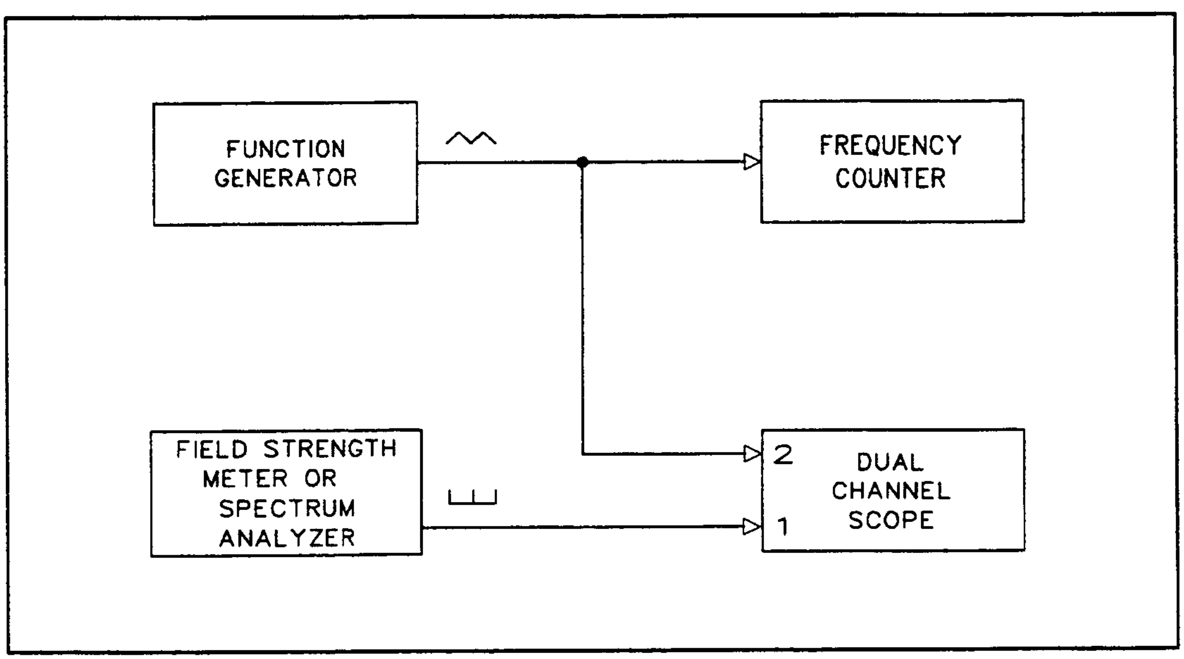
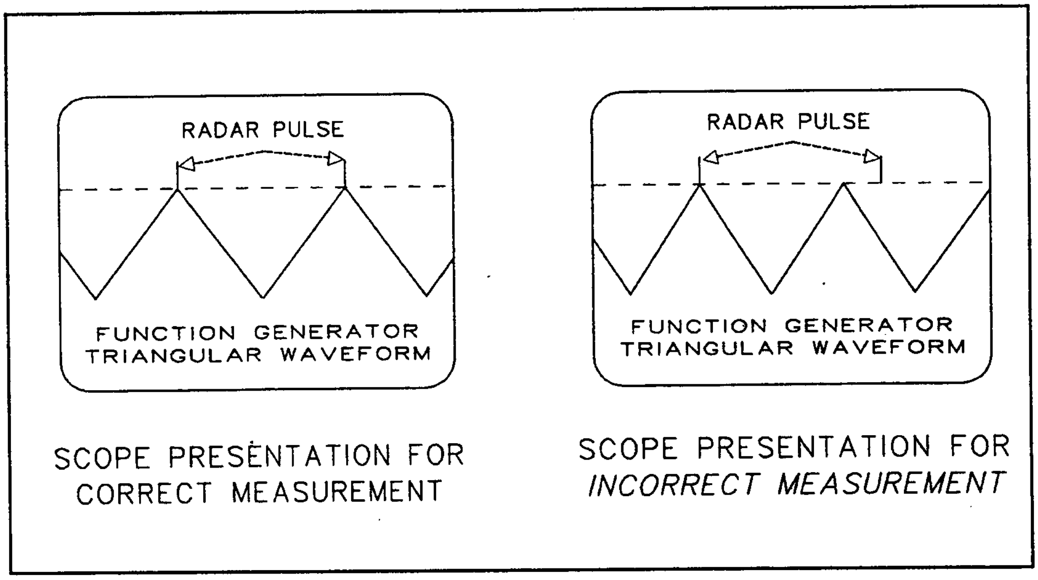


FIGURE 15-8. SCOPE DISPLAYS FOR CORRECT AND INCORRECT MEASUREMENT



1510. thru 1599. RESERVED.